Floc Dynamics and Facies Generation on the Margins of the Adriatic Sea

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LONG-TERM GOALS

The sand-mud transition is a fundamental stratigraphic boundary at which sediment size and sorting change dramatically and abruptly (Stanley et al., 1983). At the transition well-sorted sands give way to poorly sorted silts and clays. The change in sediment size and sorting makes the sand-mud transition recognizable acoustically as well as lithologically. Despite its importance, dynamical understanding of the transition is rudimentary. Understanding has evolved slowly because erosion, deposition, and transport of muds are affected strongly by the tendency of fine sediment particles to clump into large agglomerations of particles called "flocs" (Hill and McCave, 2001). The overall goal of our proposed research is to advance our process-based, mechanistic understanding of the sand-mud transition by building on the recent progress in understanding of floc dynamics.

SCIENTIFIC OBJECTIVES

Three variables are essential for proper characterization of floc transport in the coastal ocean. They are floc concentration as a function of size, floc settling velocity as a function of size, and floc fraction (Hill and McCave, 2001). Floc fraction is the fraction of the total suspended mass contained within flocs. The first general task for meeting our overall goal is to improve understanding of these three variables by simultaneously measuring them and the variables thought to control them. The second task is to establish mechanistic links between these three variables and sediment sorting in the seabed. The third task is to apply knowledge gained in tasks 1 and 2 to developing a dynamical, process-based understanding of the sand-mud transition. Within this general context our specific objectives in the EuroSTRATAFORM Adriatic field area are as follows:

- Use data on floc size and disaggregated inorganic grain size (DIGS) to develop mechanistic understanding of the rates at which suspended sediment is lost from the Po River plume and to examine the temporal evolution of the 2000 Flood deposit.

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14. ABSTRACT

The sand-mud transition is a fundamental stratigraphic boundary at which sediment size and sorting change dramatically and abruptly (Stanley et al., 1983). At the transition well-sorted sands give way to poorly sorted silts and clays. The change in sediment size and sorting makes the sand-mud transition recognizable acoustically as well as lithologically. Despite its importance, dynamical understanding of the transition is rudimentary. Understanding has evolved slowly because erosion, deposition, and transport of muds are affected strongly by the tendency of fine sediment particles to clump into large agglomerations of particles called ???flocs??? (Hill and McCave, 2001). The overall goal of our proposed research is to advance our process-based, mechanistic understanding of the sand-mud transition by building on the recent progress in understanding of floc dynamics

15. SUBJECT TERMS

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- To develop a mechanistic understanding of the sand-mud transition along the Apennine Margin by integrating surficial sediment DIGS with measurements of boundary layer stress and floc size, and in situ measurements of floc size and settling velocity.

- Extend models of floc break-up to include the mechanism proposed to produce abrupt reductions in floc size at a threshold shear (Hill et al., 2001).

- Develop, test, and implement models for quantitative process-based interpretation of disaggregated inorganic grain size in suspension and in the seabed.

APPROACH

In October 2000 the Po River experienced a 50-year return interval flood. In December 2000 a coring expedition mounted by Chuck Nittrouer, Andrea Ogston, and Rob Wheatcroft revealed a thick flood deposit in the Adriatic Sea near the mouth of the Po. Studies of the emplacement, reworking, and preservation of this flood deposit have been carried out. To examine the spatial coverage of the 2000 Po River flood deposit, seabed disaggregated inorganic size distributions were characterized for slab samples collected from box cores and x-rayed by Rob Wheatcroft. Size distributions were measured with the Coulter Multisizer IIe (Milligan and Kranck, 1991). Subsamples were closely spaced (mm-cm) throughout the cores. Sampling was more closely spaced in regions of interest on the x-rays. To examine the temporal evolution of the flood deposit the top 20cm of cores from 11 stations that have been occupied on each of 5 cruises has been sampled for DIGS.

In an effort to link plume processes to sea bed deposition, water column observations of in situ floc size, suspended material component grain size, and hydrography of the Po River and plume were made, as well as bottom sediment DIGS near the river mouth. By examining the characteristics of the river, plume and nearshore, we are able to create a better understanding of how the packaging and concentration of material in suspension affects its initial deposition near the river mouth.

We believe that the abrupt transition on continental margins from sorted silts and sands to unsorted mud is the result of deposition of flocculated sediment. To test this hypothesis, an investigation of the processes controlling the sand-mud transition along the Apennine Margin was initiated. A sampling grid extending from 6-25m depth was established off of the Pescara and Tronto Rivers. Surficial sediment samples were collected for DIGS, mineralogy, surface area, metals concentration and organic concentration. At the same time, water column profiles of floc size, SPM and hyrdrography were collected along the 20 and 25m isobaths. Water column profiles were also collected off of 5 other Apennine Rivers. Results from the work on the Po River suggested that the concentration and packaging of the sediment in the river were important factors controlling sediment removal from the plume. Samples were collected from 4 rivers draining the Apennines for concentration and DIGS. A simple still water settling experiment similar to a pipette analysis was carried out to examine particle packaging in the Chienti and Tronto Rivers. Using clearance rate and the evolution of the DIGS curves, the relative amount of flocculation in the river can be determined.

To test the effect of boundary layer shear stress on floc packaging, simultaneous measurements of floc size and bottom boundary shear stress will be made on the Apennine margin. Floc size will be characterized with a macroaggregate camera assembly (Hill et al., 2001). Shear stress will be estimated with two-horizontally displaced acoustic Doppler velocimeters (Hill et al., 2001). These

instruments will be deployed on the Apennine margin in 12 m of water off of the mouth of the Chienti River. The deployment will start in November 2002 and extend to May 2003.

In a further attempt to understand how packaging effects fine-grained sediment flux, a new instrument called INSSECT, which stands for **IN** situ **S**ize and **SE**ttling **C**olumn **T**ripod, was designed to determine the size and settling velocity of suspended material in situ, as well as capture flocs. The package includes a digital floc camera to observe the ambient floc population (Milligan, 1996, Milligan and Hill, 1998), a digital video camera to measure the size and settling velocity in the settling column, and a timed sediment trap consisting of 24 programmable cups containing polyacrylamide gel to collect flocs intact. Also mounted on the INSSECT are a LISST, OBS and a compass/tilt package. INSSECT is scheduled for testing in the fall of 2002, and deployment on the Apennine Margin in February 2003. Results from this instrument will be used to determine the mass versus size relationship for flocs on the Apennine Margin directly, thereby eliminating the need to assume an idealized settling law (Curran et al., 2002b).

All work is being conducted collaboratively between Paul Hill of Dalhousie University and Tim Milligan of Bedford Institute of Oceanography. Milligan takes primary responsibility for equipment design, data acquisition, and particle size analysis. Hill takes primary responsibility for modelling, data analysis, and communication of results.

WORK COMPLETED

Cruises were carried out off of the Po River and along the Apennine Margin in October 2001 and April 2002. One manuscript was published in *Continental Shelf Research*. It interprets the loss rates of component grain sizes from suspension in a laboratory flume in the context of our simple model of particle aggregation/disaggregation (Curran et al., 2002c). A second manuscript is in press in *Continental Shelf Research* (Curran et al., 2002b). It describes our new hypothesis regarding sediment resupply to the Eel River plume from the nearshore. A third manuscript is also in press by the *Journal of Sea Research*. It describes secondary flocculation in enclosed settling columns and its implications for field applications (Curran et al., 2002a).

Kristian Curran successfully completed his Masters degree using data from the STRATAFORM project on the Eel margin. He took a lead role in data analysis, and he has applied the parameterization of sediment partitioning in suspension to the interpretation of the evolution of DIGS in the Eel plume and two laboratory studies. A total of three manuscripts have been submitted or published as the result of this work.

Jason Fox completed his second year of work as a student, with his focus on the Po dispersal system. He took a lead role in data collection during our June and October 2001 cruises to the Po delta. Several hundred floc images and numerous suspended sediment samples on a grid of stations overlying the 2000 flood deposit and in the Po River have been collected and analyzed. A manuscript describing the settling behaviour of material from the Po River has been completed and is undergoing internal review.

Doug George completed his first year of courses and carried out sample collection on the Apennine Margin, concentrating primarily on the sand-mud transition off of the Pescara and Tronto Rivers. 165 surficial sediment samples were collected and are being analyzed for DIGS, mineralogy, surface area,

metals concentration and organic concentration. These data will be used to examine the relative contribution of the Apennine rivers to the Western Adriatic Margin. Surficial sediments from box cores were also collected for DIGS analysis on a grid of stations along the Western Adriatic between the Po and Sangro Rivers.

Dr. Ole Mikkelsen has overseen the construction phase for the new INSSECT package. In addition to these responsibilities, he has carried out an inter-comparison exercise with the digital floc camera and a LISST. Data has been collected from Newark Bay (in collaboration with Dr. Bob Chant of Rutgers University), and in the several bays and inlets in Eastern Canada. A series of hourly in situ floc images taken over a 3-month period of a spring bloom has also been analyzed and a manuscript is in preparation.

Sub-samples from x-rayed slabs gathered by Rob Wheatcroft, Chuck Nittrouer, and Andrea Ogston during 5 cruises from December 2000 to April 2002 were collected and analysed for DIGS to examine the temporal evolution of the flood deposit.

The basins of 4 Apennine Rivers were sampled, and the presence of flow diversions catalogued for use in the selection of the offshore instrument sites. Total concentration and DIGS samples were collected, and the degree of flocculation in the Chienti and Tronto Rivers was determined using a still water settling experiment. Offshore hydrographic transects were also carried out to characterize in situ floc size and concentration off of the major Apennine Rivers.

Ongoing collaboration with Pat Wiberg has led to advances in the parameterization of particle size in bottom boundary layers. She has devoted some attention to the effect of several different break-up parameterizations on predicted spatial patterns of DIGS. During the Apennine margin cruise, measurements of erosional shear stress were made using a Gust Chamber. DIGS analysis was performed on the top 1mm of the sediment remaining in the chambers after erosion.

RESULTS

A collaboration with Dr. Alfredo Boldrin of the Instituto di Biologia del Mare (IMB), Consiglio Nazionale delle Ricerche in Venice was developed during the fieldwork carried out in June 2001. Initial assessment of data from the Po River plume in June indicated that sediment was lost rapidly from the plume in the form of flocs. Additional sampling was carried out with IMB in October 2001 to observe floc properties in the water column both off shore of the Po River mouth, and in the river. In situ floc images and observations of the clearance of river water samples during settling indicated that the Po River was highly flocculated. The flocculated nature of the river is likely a major factor in the rapid clearance observed at the river mouth. Offshore transects sampled with IMB from the *d'Ancona* showed that although the bulk of the material discharged by the Po has been removed from suspension landward of the 10m isobath, an optically significant plume persists. Plumes containing very little mass in suspension but possessing strong attenuation also characterized the water column along the Apennine Margin.

In contrast to the Po Margin where the sand-mud transition was located inside the 10m isobath and in one case directly off of the mouth within 5m depth, the transition on the Apennine margin was located at depths of 15-20 m. Our hypothesis is that two major factors govern the formation of an abrupt transition to floc-settled unsorted sediment: high concentration and low turbulence. Decreased

sediment load in the Apennine rivers due to flood control and hydro-electric power generation has conceivably altered the concentration of fine grained sediment discharged to the Apennine Margin, resulting in a shift of the sand-mud transition offshore. The results from our grain size analysis will be compared to those of Passega et al. (1967) for the Pescara River to determine if shift in sediment texture has occurred. The second factor, turbulence in the boundary layer causing floc break-up, will be investigated starting in November 2002.

IMPACT/APPLICATION

Observations are helping to refine understanding of modes of delivery of fine-grained sediment from rivers and its incorporation into the sedimentary record. These observations suggest that the sand-mud transition, characterized by an abrupt change in sediment size and sorting, is the result of both high concentration and low turbulence. The generalized parameterization of particle aggregation and disaggregation rates will ease incorporation of these important processes into models of fine sediment transport and deposition.

TRANSITIONS

No Transitions

RELATED PROJECTS

The proposed parameterization of aggregation and disaggregation is being applied successfully to the interpretation of optical measurements gathered at the Coastal Mixing and Optics site by Oregon State University researchers. Collaborator is Emmanuel Boss (OSU).

Floc size versus settling velocity relationships and their dependence on fluid stress are being investigated with support from the Natural Sciences and Engineering Research Council in Canada.

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